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# 40 PROFIBUS Networks

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## INTRODUCTION

PROFIBUS (process field bus) is a standardized, open communication system for all areas of application in factory and process automation. The technology was introduced in the early 1990s and has been developed continuously ever since. From the historical point of view, the first PROFIBUS protocol was PROFIBUS FMS (fieldbus message specification), which was conceived as a universal data communication standard for machinery and plant. It did not prove successful in factory and process automation, among other reasons, because of its complexity. PROFIBUS DP (decentralized periphery), introduced in 1993, is an optimized variant for the quick and simple connection of input and output (I/O) units to a control system. PROFIBUS PA (process automation), which followed soon afterward, addresses the special requirements of process automation, in particular, the need for intrinsically safe bus powering of field devices. PROFIBUS DP and PROFIBUS PA technologies are specified in the international standards EN 50170 [1] and IEC 61158 [2] and are suitable for replacement of conventional discrete and analog signals in control systems.

As its popularity increased, the PROFIBUS DP specifications were extended to include a number of common but optional application profiles, for example, safety and time stamping. Similarly, several application profiles were developed to meet the needs of specific device types, for example, measuring devices, drives, and remote I/Os. By the end of the millennium, the PROFIBUS DP/PA standard had covered many of the requirements of both factory and process automation, from field to control level, as shown in [Figure 40.1](#). It was rewarded by a large degree of support from both equipment manufacturers and users and today has an installed base of over 30,000,000 I/O points.

At this point in time, however, Ethernet had already begun to work its way down from the office environment on

to the factory floor and was being seen as the future standard for control system backbones. Office Ethernet is in itself not suitable for control systems, since media access is stochastic, not deterministic, so there was a need to develop a further standard for the operations level. The result was the PROFINET (process field network) specification, standardized in IEC 61158 [2], which addresses not only the problems of deterministic control for real-time (RT) and isochronal RT applications but also those of network engineering, operation, and I/O integration of control and fieldbus networks. In the meantime, PROFINET has developed into an open, scalable protocol, which can be applied to many areas of production and which supports integrated communication from field to enterprise level.

PROFIBUS is supported by PROFIBUS and PROFINET International [3], which is a worldwide association of PROFIBUS user organizations. It is responsible for the development of the standard, its maintenance, the conformance testing of PROFIBUS devices, as well as the issuing of device certificates. It has a number of independent accredited PROFIBUS Competence Centers throughout the world, which maintain test facilities that are accessible for users and offer training courses for prospective PROFIBUS engineers.

## PROFIBUS DP

PROFIBUS DP was specified in the original PROFIBUS standard and is designed for fast data exchange at control and field level. It is standardized in EN 50170 [4], IEC 61158, and IEC 61784. PROFIBUS DP supports the implementation of both mono-master and multi-master systems, affording a high degree of flexibility during system configuration. A maximum of 126 devices (masters or slaves) can be connected to a bus. In mono-master systems, only one master is active on the bus during operation of the system. The device types are as follows:

- *DP Master Class 1 (DP-M1)* is a central controller that cyclically exchanges information with the distributed stations (slaves) at a specified message cycle. Typical DP-M1 devices are programmable logic controllers (PLCs) or PCs.

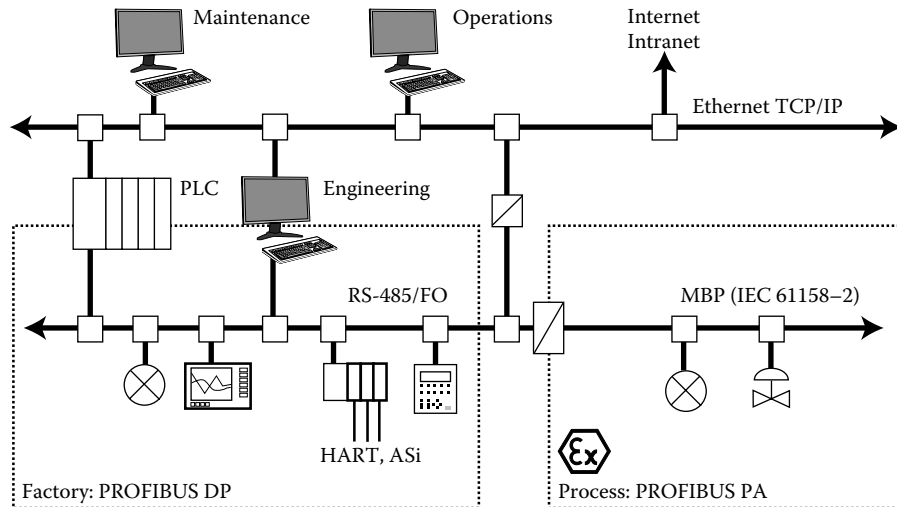


**FIG. 40.1**  
Overview of PROFIBUS DP and PA technologies.

- *DP Master Class 2 (DPM2)* is an engineering, configuration, or operating device with active bus access; however, it does not have to be permanently connected to the bus system.
- *Slaves* are peripherals (I/O devices, remote I/Os, drives, HMIs, valves, transducers, analyzers) that read in-process information and/or use output information to intervene in the process. There are also devices that solely process I/O information.

Figure 40.2 gives an overview of PROFIBUS DP system standards. The PROFIBUS DP physical layer is based on RS485 (NRZ), RS485-IS, or fiber optics. PROFIBUS PA uses the Manchester Bus Powered (MBP, MBP-LP, or MBP-IS) physical layer to IEC 61158-2.

PROFIBUS DP communication technology is at the core of the standard. The original version, DPV0, contained the basic functions for cyclic data communication. Extensions to the original protocol addressed the higher demands made

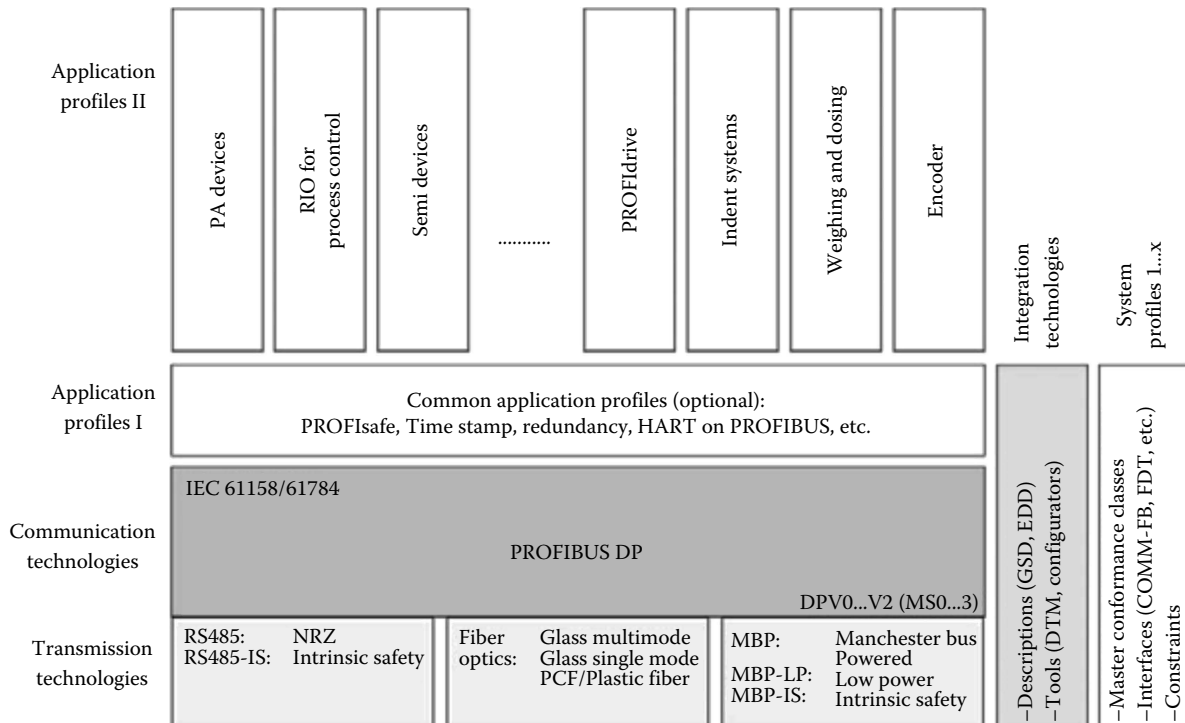


**FIG. 40.2**  
Overview of PROFIBUS DP system standards.

by parameterization, configuration, and operation of intelligent field devices. Subsequent extensions, DPV1 and DPV2, are concerned with additional functions for acyclic communication. DPV1 specifies additional services for the parameterization, operation, monitoring, and alarm handling of field devices parallel to and independent of the cyclic communication. DPV2 extends the available functions to meet the demands of drives for a rapid and clock-synchronized communication between two slaves in the field. It specifies slave-to-slave communication via broadcast as well as functions for isosynchronous transmission, clocking, and upload/download functions.

Seen from the point of view of data exchange, that is, master–slave or slave–slave, the communication protocol used by a device varies according to its role in the network and its relationship to its communication partner. Here, four distinct variants exist:

1. The MS0 protocol governs cyclic communication between a Class 1 master and slave. In addition to process and set point values, the MS0 protocol is also used for the transmission of station, module, or channel-specific diagnosis information.
2. The MS1 protocol governs acyclic communication between a Class 1 master and slave.
3. The MS2 protocol governs acyclic communication between a Class 2 master and slave.
4. The MS3 protocol governs the broadcast communication between two slaves.

Acyclic communication is always of secondary importance for a Class 1 master. It takes place in the period between the completion of all cyclic communication and the elapsing of the total slot time allocated to the master. For a Class 2 master, the entire total slot time is available for acyclic communication.

The common application profiles are optional protocols for various aspects of network management including safety functions. PROFIsafe is of note here and is briefly discussed in the following. At the time of writing there are 14 different device application profiles, five of which address the specific needs of process automation. The profiles are specific protocols for particular device types or applications, for example, measuring devices or motion control. PROFIBUS PA device profiles are important in process control applications, PROFIdrive for motion control.

The integration technology provides the means of integrating and operating PROFIBUS devices. Finally the system and master profiles describe the system performance that is available to field devices. Table 40.1 gives an overview of the relationship between the various system standards and the applications for which they are used.

The “toolbox” approach of the PROFIBUS DP system standards facilitates the development of new devices. For example, a manufacturer of weighing machines intended for operation in Dust-Ex might choose to equip his product with a RS485-IS physical layer, DPV1 technology, and the weighing and dosing application profile. Similarly, a manufacturer of field devices intended for use in hazardous areas would equip his device with a MBP-IS physical layer, DPV1 technology, and the PROFIBUS PA device profile. Finally, a manufacturer producing a remote I/O for the integration of HART devices would use DPV1 technology, the HART on PROFIBUS common profile, and the application profile for process control.

### Application Profiles

In addition to the PROFIBUS PA profile, which is discussed in detail later, two application profiles are worth a short explanation: PROFIsafe is relevant to safety functions and PROFIdrive to motion control.

*PROFIsafe* is an optional, common application profile that allows safety-relevant devices to be connected to the same single transmission line as standard devices. These then communicate with an additional safety PLC or a combined standard/safety controller. PROFIsafe is intended for applications such as presses, saws, robots, burners, etc., where special precautions are necessary to avoid risk to operators, environment, or investment. Chemical processes must also be closed down safely, should an abnormal safety condition demand it. Traditionally, safety systems are hard-wired, that is, based on relays or a similar trusted and tangible technology. In recent years, however, safety automation has seen an influx of microcontrollers, software, and communication networks, which have now been proven in use in millions of applications. The basis for their use is laid down in international safety standard IEC 61508 [5]. This details the measures required for the detection and management of errors and failures, together with the description of systematic software development processes.

PROFIsafe, in fulfilling the requirements of NAMUR Recommendation NE97 [6] on fieldbus safety systems,

**TABLE 40.1**

*Target Applications and Typical Use of PROFIBUS Profiles, Protocols, and Transmission Standards*

| Target Application     | Factory Automation       | Motion Control       | Process Automation   | Safety               |
|------------------------|--------------------------|----------------------|----------------------|----------------------|
| Typical designation    | PROFIBUS DP              | PROFIdrive           | PROFIBUS PA          | PROFIsafe            |
| Application profile    | None or specific profile | PROFIdrive profile   | PA device profile    | PROFIsafe profile    |
| Communication protocol | PROFIBUS DP protocol     | PROFIBUS DP protocol | PROFIBUS DP protocol | PROFIBUS DP protocol |
| Transmission standard  | RS485                    | RS485                | RS485; MBP-IS        | RS485; MBP-IS        |

merges standard automation and safety automation in one technology. It is available in products such as programmable and numerical controllers, remote I/Os, laser scanners, light curtains, motor starters, frequency converters, drives, gas and fire sensors, and so on. Its safety measures are added to the device as a safety layer on top of the existing PROFIBUS layers in the communication stack. This layer is responsible for the transmission of safety-relevant process data (safety application) as well as the existing standard application for non-safety critical functions, for example, diagnosis, which is unchanged. Different industry requirements are taken into account by the provision of two different process data lengths of 12 and 122 bytes, respectively. The first is for the short signals met in factory automation, which must be processed at very high speed; while the second is for the longer process values met in process automation.

*PROFIdrive* is an application profile that addresses the specific requirements of motion control. It utilizes the new functions realized in PROFIBUS version DPV2: clock cycle synchronization and slave-to-slave communication, and allows intelligent drives to be used in decentralized automation structures. Digital servo-drives can also be synchronized and position control loops can be closed via PROFIBUS. *PROFIdrive* defines the three generic application classes: standard drives, standard drives with technological function, and positioning drives. It finds widespread use in factory automation in applications ranging from conveying systems through textile and printing machines to bottling and packing machines. It is not of relevance to process automation, although field devices and actuators may be built into the machines. More information can be found at the PROFIBUS site, reference [3].

### Version DPV1 Architecture

As mentioned earlier, PROFIBUS Version DPV1 is used primarily for process automation applications and is closely connected with the PROFIBUS PA application profile. In this

combination, PROFIBUS DP acts as the fast control network and PROFIBUS PA as the slower fieldbus network. It is, however, a network in its own right and has corresponding specifications regarding topology, physical layer, and bus access. Table 40.2 summarizes the principle technical data.

Figure 40.3 shows a typical architecture. When used in conjunction with PROFIBUS PA, the architecture often comprises a PLC and a personal or laptop computer equipped with a PROFIBUS DP card, on which the engineering tools are installed. Where an independent maintenance system is required, it is also possible to bypass the controller via an Ethernet/PROFIBUS DP gateway. All other devices are slaves, independent of whether they are PROFIBUS DP or PROFIBUS PA. These might include field devices such as flow meters or analyzers, recorders and displays, remote I/Os, and couplers/links for the PROFIBUS PA connection.

PROFIBUS DP is based on a linear topology, whereby for lower data transmission rates, a tree structure is possible. EN 50170 specifies two types of copper bus cable. For transmission rates up to 12 Mbit/s, cable type A is recommended. The specification is given in Table 40.3.

The maximum permissible cable length depends upon the transmission rate. For PROFIBUS RS485 cable of type A, the dependency is as shown in Table 40.4.

The actual cable length allowable, however, may be dependent on the devices connected to it. A maximum of 32 participants is allowed per segment, whereby both ends of the segment must be equipped with a 220  $\Omega$  active terminating resistance. PROFIBUS DP Type A cable is available from a number of manufacturers. Bus terminators are available separately or are built into network components. There is no standard connector, so that, depending on the manufacturer, cables may be connected by screw terminals, plugs, and “DB9” connectors (proper designation DE9). One DB9 connector system on the market features a switchable terminal resistor and bus-monitoring LEDs. The connectors can be used in a “piggyback” fashion, making for extremely easy installation and maintenance of the bus.

**TABLE 40.2**

*Principle Technical Data of PROFIBUS DP Version DPV1*

| <i>Property</i>   | <i>Description</i>                                                                                      |
|-------------------|---------------------------------------------------------------------------------------------------------|
| Standard          | DIN 19245 Parts 1–3, Version DPV1; EN 50179; IEC 61158                                                  |
| Protocol          | PROFIBUS                                                                                                |
| Topology          | Linear, tree, ring (fiber optics)                                                                       |
| Physical layer    | RS485 (NRZ), RS485-IS and/or fiber optics                                                               |
| Bus length        | Copper: max. 1200 m (3900 ft) without repeaters, depending upon transmission rate; fiber optics: >15 km |
| Bus termination   | Active terminator, 350/220/350 $\Omega$                                                                 |
| Telegram length   | Max. 244 bytes                                                                                          |
| Data security     | Horizontal and cross parity, hamming distance 4                                                         |
| Transmission rate | 9600 bit/s up to 12 Mbit/s in defined steps                                                             |
| Bus access method | Master–slave, with token passing                                                                        |
| Participants      | Max 126 (using repeaters), including max. 32 as masters; Per segment: max 32                            |

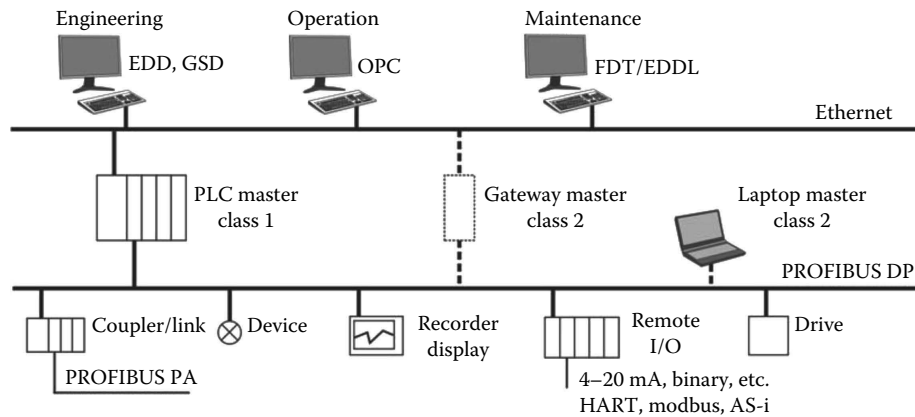


**FIG. 40.3**  
*Typical PROFIBUS DPV1 architecture.*

**TABLE 40.3**  
*Specifications of PROFIBUS DP Cable Type A*

|                    |                                                                 |
|--------------------|-----------------------------------------------------------------|
| Impedance          | 135–165 $\Omega$ at a measuring frequency of 3–20 MHz           |
| Cable capacitance  | <30 pF per meter                                                |
| Core cross section | >0.34 mm <sup>2</sup> , corresponds to AWG 22                   |
| Cable type         | Twisted pairs, 1 $\times$ 2, 2 $\times$ 2, or 1 $\times$ 4 core |
| Loop resistance    | 110 $\Omega$ /km                                                |
| Signal attenuation | Max. 9 dB over the entire length of the segment                 |
| Screening          | Woven copper sheath or woven sheath and foil sheath             |

The bus length and/or the number of participants can be increased by using repeaters. Up to nine repeaters are allowed, allowing a maximum length of 2000 m at a transmission rate of 1.5 Mbit/s. Since a repeater itself is considered to be a bus participant, the maximum number of participants is 126 minus the number of repeaters. The first and last segments may contain up to 31 participants, the segments between repeaters may contain up to 30 participants. For transmission rates up to 1.5 Mbit/s, devices may be connected to the bus by spurs, that is, to a T-box on the bus. The total length (sum) of all spurs may not exceed 6.6 m. Spurs should not be used for transmission rates greater than 1.5 Mbit/s. Figure 40.4 shows examples of a linear and tree bus structure using three repeaters.

PROFIBUS DP can also be used in explosion-hazardous areas. A corresponding PROFIBUS guideline is available that specifies the configuration of intrinsically safe RS485 solutions with simple device interchangeability [7]. In contrast

to the FISCO (fieldbus intrinsically safe concept) model, see later, for which there is only one active supply device per segment, all stations represent active sources. The devices are supplied with external energy and can feed this to the bus. RS485-IS segments are coupled to RS485 safe segments by means of so-called fieldbus isolating repeaters. Up to 32 intrinsically safe stations can be connected to the bus circuit, provided they are designed according to the guidelines (see Table 40.5). Not only cables, but also components and terminators must also conform to the specification. More details can be found in the specification.

If a PROFIBUS DP segment runs through an explosion-hazardous area, it must be executed with a degree of protection “increased safety” “e.” For copper cabling, the number of devices per segment is limited to four. Proof of intrinsic safety is required for every segment, since every intrinsically safe component has different electrical characteristics. The cable and spurs must be included in the calculation. The exchange of a component from one manufacturer by a component from another manufacture always requires renewed proof of intrinsic safety.

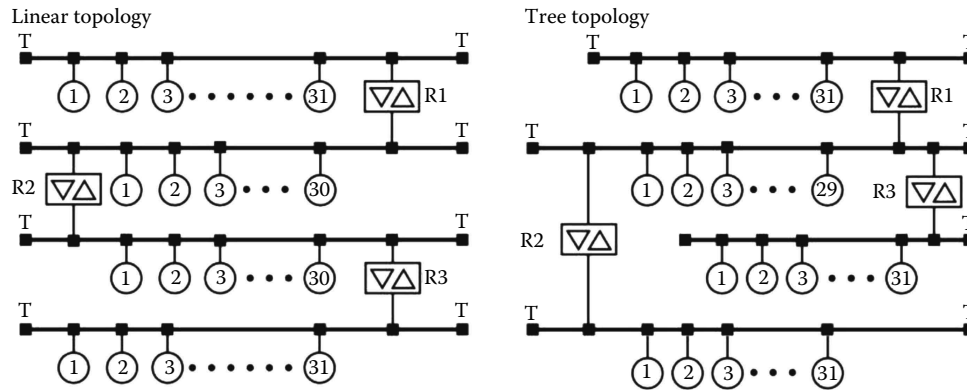
An alternative to RS485-IS is an optical or mixed optical/copper network. This can also be used where the PROFIBUS DP system has to be routed over large distances or in plant with heavy electromagnetic interference. Provided that all participants support them, very high transmission rates are possible.

### Version DPV1 Media Access

PROFIBUS DPV1 uses a hybrid access method of centralized master/slave and decentralized token passing (see

**TABLE 40.4**  
*Maximum Lengths of Type A Cable as a Function of Transmission Rate*

|                            |                         |       |     |      |                    |
|----------------------------|-------------------------|-------|-----|------|--------------------|
| Transmission rate (kbit/s) | 9.6; 19.2; 45.45; 93.75 | 187.5 | 500 | 1500 | 3000; 6000; 12,000 |
| Cable length (m)           | 1200                    | 1000  | 400 | 200  | 100                |

**FIG. 40.4**

PROFIBUS DP system with linear structure and tree structure (T, terminator; R, repeater, 1 ... n = maximum number of field devices on a segment).

**TABLE 40.5**

PROFIBUS RS485-IS: List of Safety-Relevant Parameters

| Parameter                              | Description                      | Value     | Remarks                                                       |
|----------------------------------------|----------------------------------|-----------|---------------------------------------------------------------|
| <i>Bus system</i>                      |                                  |           |                                                               |
| Maximum input voltage                  | $U_i$ (V)                        | $\pm 4.2$ |                                                               |
| Maximum input current                  | $I_i$ (A)                        | 4.8       |                                                               |
| Maximum inductance to resistance ratio | $L'/R'$ ( $\mu\text{H}/\Omega$ ) | 15        | For the whole operating temperature range of the bus system   |
| Number of devices                      | $N_{\text{TN}}$                  | Up to 32  |                                                               |
| <i>Communication device</i>            |                                  |           |                                                               |
| Maximum output voltage                 | $U_o$ (V)                        | $\pm 4.2$ |                                                               |
| Maximum output current                 | $I_o$ (mA)                       | 149       | Total current from wires A, B, and supply for bus termination |
| Maximum input voltage                  | $U_i$ (V)                        | $\pm 4.2$ |                                                               |
| Maximum internal inductance            | $L_i$ (H)                        | 0         |                                                               |
| Maximum internal capacitance           | $C_i$ (nF)                       | N/A       | Insignificant for safety                                      |
| <i>External active bus termination</i> |                                  |           |                                                               |
| Maximum output voltage                 | $U_o$ (V)                        | $\pm 4.2$ |                                                               |
| Maximum output current                 | $I_o$ (mA)                       | 16        |                                                               |
| Maximum input voltage                  | $U_i$ (V)                        | $\pm 4.2$ |                                                               |
| Maximum internal inductance            | $L_i$ (H)                        | 0         |                                                               |
| Maximum internal capacitance           | $C_i$ (nF)                       | N/A       | Insignificant for safety                                      |

Figure 40.5). The masters build a logical token ring. When a master possesses the token, it has the right to transmit and can now talk with its slaves in a master–slave relationship for a defined period of time. At the end of this time, the token must be passed on to the next active device in the token ring.

In a typical PROFIBUS DPV1 network, there is one Master Class 1 device, the controller or process control system, one Master Class 2 device, for example, a gateway or a PC with a device configuration tool, and the slaves. A slave may be assigned to only one Class 1 master. The slaves of a Class 2 master may also be assigned to a Class 1 master.

In Phase A, Figure 40.5, the Class 1 master communicates cyclically with the slaves assigned to it (in this case S1 to S5) using the MS0 protocol. The remainder of the slot time is available for acyclic communication with the slaves using the MS1 protocol. When a predetermined period of time has elapsed, the token is passed to the next master in the token ring. In Phase B, the Class 2 master communicates acyclically with its slaves, that is, on demand, using the MS2 protocol. Acyclic communication is used for commissioning as well as for device configuration, diagnosis, and alarm handling during normal operation.

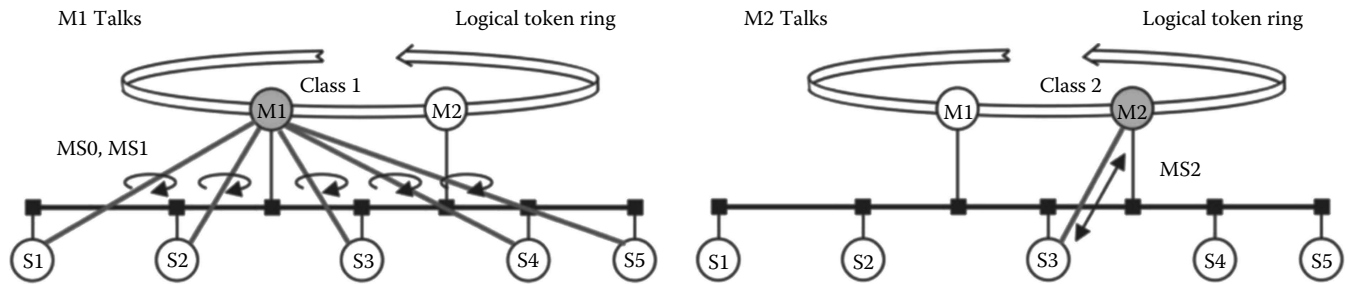


**FIG. 40.5**  
PROFIBUS DPV1 media access.

### PROFIBUS DPV1 Network Configuration

A prerequisite for communication on the bus is the correct addressing of the participants. Every participant in the PROFIBUS DP system is assigned a unique address between 0 and 125 (cyclic data transmission). Normally, the low addresses are assigned to the masters. The addresses may be assigned by DIP switch, local operating elements, and device software, or by an operating program. It is good practice to use consecutive addresses, starting from “0,” as this allows more efficient operation. If two devices are assigned the same address, this will lead to communication conflicts and they will not be seen in the live list of the network configuration tool.

In order to integrate the field devices into the bus system, the network configuration tool requires a description of the device parameters, parameter length, and transmission rates supported. These data are contained in the general station

data (GSD) file. In addition, device bit maps are required, which appear as icons in the network tree, as well as extended device description (EDDs) files. The normal procedure is to build up a virtual network in the network configuration tool complete with tags and addresses. Then, the bus parameters are set and the parameters to be transmitted over the bus by the devices are configured. The connection to the physical network is now made and the project is downloaded to the controller. When online, a live list of the devices in the network serves as an initial check of functionality. The configuration tool will also offer a number of diagnostic aids, which enable faults to be found and remedied, for example, mismatch of EDD or GSD version.

All active components (masters) on the bus must operate with the same bus parameters. Normally, the network configuration tool will offer the master’s default bus parameters, which are dependent on the selected transmission rate, Figure 40.6. Alternatively, the parameters may be set using a

| Edit Bus Parameter                                                                                             |         |         |  |
|----------------------------------------------------------------------------------------------------------------|---------|---------|--|
| Baud rate                                                                                                      | 187,5   | kBits/s |  |
| Slot Time                                                                                                      | 100     | tBit    |  |
| Min. Station Delay of Responders                                                                               | 11      | tBit    |  |
| Max. Station Delay of Responders                                                                               | 60      | tBit    |  |
| Quiet Time                                                                                                     | 0       | tBit    |  |
| Setup Time                                                                                                     | 1       | tBit    |  |
| Target Rotation Time                                                                                           | 2270    | tBit    |  |
| Target Rotation Time                                                                                           | 12.1067 | ms      |  |
| GAP Actualization Factor                                                                                       | 10      |         |  |
| Max Retry Limit                                                                                                | 1       |         |  |
| Highest Station Address                                                                                        | 119     |         |  |
| Tid1                                                                                                           | 37      | tBit    |  |
| Tid2                                                                                                           | 60      | tBit    |  |
| Poll Timeout                                                                                                   | 10      | ms      |  |
| Data Control Time                                                                                              | 1200    | ms      |  |
| Min Slave Interval                                                                                             | 25.000  | ms      |  |
| Watchdog control                                                                                               | 200     | ms      |  |
| Auto Clear<br><input checked="" type="radio"/> Auto clear mode OFF<br><input type="radio"/> Auto clear mode ON |         |         |  |

**FIG. 40.6**  
Example of PROFIBUS DP bus parameters in a network configuration tool.

FDT (field device tool) or EDD plant asset management tool. Where the master is operating alone on the bus, the parameters need no adjustment. If two or more masters are present, or if a PROFIBUS DP/PA segment coupler is on the bus, then the parameters must be changed according to the instructions provided by the manufacturer of the auxiliary devices. In all cases, the highest station address, that is, the highest slave address, on the bus must be entered.

All participants in a PROFIBUS DP system must support the transmission rate set at the master. This means that the speed of data exchange is determined by the slowest participant. Device transmission rates are usually adjusted by DIP switches, local operating elements, device software, etc., or the device may sense the bus and adjust its rate automatically.

Data are exchanged over PROFIBUS DP by means of standard telegrams, which are transmitted via the media access interface. The permissible telegram length of reference data is specified in the PROFIBUS DP protocol at 244 bytes. It should be noted, however, that some controllers only support a maximum telegram length of 122 bytes. This restriction is normally of no consequence to PROFIBUS DP devices.

PROFIBUS DPV1 devices may transmit both input and output values. In general, measured value and status inputs

require 5 bytes, display values and status outputs require 5 bytes, limit values and status require 2 bytes, and control output values generally require 1 byte per action, the actual number required being dependent upon device. An instrument offering several measured values may transmit correspondingly more bytes. In the case of the flowmeter shown in Figure 40.7, the telegram may have a maximum length of 57 bytes, 45 bytes input and 12 bytes output, depending upon the parameters selected for transmission on the bus. Five analog inputs, for example, flow, mass flow, normalized flow, temperature, viscosity, and three totalizers can be selected as input. Outputs are the totalizer reset and the display value, which is supplied by the controller for display on the device. In the example, the outputs have fixed slots, and unwanted outputs between enabled slots must be filled with an “empty module” or “free space” marker. The total number of inputs and outputs enabled then determine the telegram length. The same telegram is used for transmission to and from the PLC.

In addition to the configuration or the slave I/O data, all devices must be set up to operate correctly. Some PROFIBUS DP devices provide local configuration elements, for example, a display; all can be configured remotely from a central maintenance station on the network using either FDT- or EDD-based tools. More details are to be found in the section on device configuration.

**Slave Configuration**

General

Device: PROMASS 83 DP Station address: 5

Description: FT101

☒ Activate device in actual configuration

☒ Enable watchdog control GSD file: EH3X1529.GSD

Max. length of in-/output data: 57 Byte Length of in-/output data: 5 Byte

Max. length of input data: 45 Byte Length of input data: 5 Byte

Max. length of output data: 12 Byte Length of output data: 0 Byte

Max. number of modules: 11 Number of modules: 1

| Module                   | Inputs | Outputs | In/Out | Identifier  |
|--------------------------|--------|---------|--------|-------------|
| EMPTY_MODULE             |        |         |        | 0x00        |
| AI                       | 5 Byte |         |        | 0x42, 0x84, |
| TOTAL                    | 5 Byte |         |        | 0x41, 0x84, |
| SETTOT_TOTAL             | 5 Byte | 1 Byte  |        | 0xC1, 0x80, |
| SETTOT_MODULETOTAL_TOTAL | 5 Byte | 2 Byte  |        | 0xC1, 0x81, |
| DISPLAY_VALUE            |        | 5 Byte  |        | 0x82, 0x84, |

| Slot | Idx | Module | Symbol  | Type | I Addr. | I Len. | Type | O Addr. | O Len. |
|------|-----|--------|---------|------|---------|--------|------|---------|--------|
| 0    | 1   | AI     | Module1 | IB   | 0       | 5      |      |         |        |

Assigned master: Station address 1 C0104 1 / ControlCare SFC173

Actual slave: Station address 5 FT101 5 / PROMASS 83 DP

Buttons: OK, Cancel, Parameter Data..., DPV1 Settings..., Append Module, Remove Module, Insert Module, Predefined Modules, Symbolic Names

**FIG. 40.7**  
PROFIBUS DPV1 slave configuration.

**PROFIBUS PA**

PROFIBUS PA has been designed to satisfy the requirements of process engineering. There are three major differences when compared to a PROFIBUS DP system:

- PROFIBUS PA supports the use of devices in explosion-hazardous areas without the need for specific proof of intrinsic safety through the FISCO concept.
- Two-wire devices can be powered over the bus cable.
- Data are transferred via the IEC 61158-2 physical layer, which allows great freedom in the selection of the bus topology.

The most important technical data are listed in Table 40.6.

**TABLE 40.6**

*Principle Technical Data of PROFIBUS PA*

|                                       |                                                                                |
|---------------------------------------|--------------------------------------------------------------------------------|
| Standard                              | IEC 61158                                                                      |
| Support                               | PROFIBUS user organization (PNO)                                               |
| Physical layer                        | IEC 61158-2, Manchester coding bus powered (MBP)                               |
| Max. length from segment coupler/link | 1900 m/6180 ft: Standard and Zone 2 (Ex ib); 1000 m/3240 ft: Zone 1 (Ex ia)    |
| Bus termination                       | 100 $\Omega$ passive                                                           |
| Max. number of participants           | 10 in hazardous areas (Ex ia); 24 in hazardous areas (Ex ib); 32 in safe areas |
| Transmission rate                     | 31.25 kbit/s                                                                   |
| Bus access method                     | Master–slave                                                                   |
| Communication protocol                | PROFIBUS DP, MS0, MS1, MS2                                                     |

**PROFIBUS PA Architecture**

PROFIBUS PA is normally used in conjunction with a supervisory PROFIBUS DP control system. The field devices on the PROFIBUS PA segment may be measuring instruments, limit switches, or actuators. Since the physical layer and transmission rates of PROFIBUS DP and PROFIBUS PA are different, the PROFIBUS PA segment is connected to the PROFIBUS DP system via a segment coupler or link (Figure 40.8).

A segment coupler comprises a signal coupler and bus power unit and modulates the RS485 signals to the MBP signal level and vice versa. From the standpoint of the bus protocol, it is transparent. In contrast, a link comprises an intelligent interface and one or more segment couplers, whereby the couplers may exhibit different types of protection. Links differ from pure segment couplers by the fact that they are PROFIBUS DP slaves on one side and PROFIBUS PA masters on the other. There is no direct communication between the PROFIBUS DP master and the PROFIBUS PA slaves, that is, the link is not transparent. For both couplers and links, the transmission rate for PROFIBUS PA is fixed at 31.25 kbit/s. A range of transmission rates may be supported on the PROFIBUS DP side.

PROFIBUS PA specifies three types of segment coupler, which differ in the type of protection provided (see Table 40.7). The actual number of devices that can be accommodated on a segment depends on their total current consumption and may be less than the maximum stated. In practice, only Type A and Type C are on the market, and with the introduction of the multibarrier concept for connecting intrinsically safe devices described later in this section, even the Type A coupler has lost some of its significance.

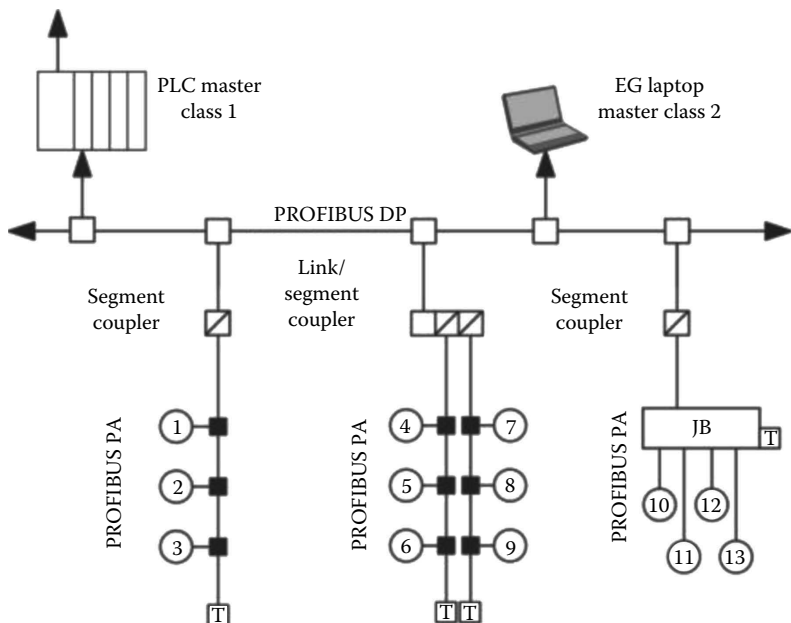


**FIG. 40.8**

*Integration of PROFIBUS PA segments into a PROFIBUS DP system using segment couplers and links.*

**TABLE 40.7***Technical Data of Standard PROFIBUS PA Segment Couplers*

| Segment Coupler         | Type A          | Type B       | Type C  |
|-------------------------|-----------------|--------------|---------|
| Type of protection      | EEx [ia/ib] IIC | EEx [ib] IIB | None-Ex |
| Supply voltage, V       | 13.5            | 13.5         | 24      |
| Max. power, W           | 1.8             | 3.9          | 9.1     |
| Max. supply current, mA | ≤110            | ≤280         | ≤400    |
| No. of devices          | Max. 10         | Max. 24      | Max. 32 |

The field devices on the PROFIBUS PA segment communicate with a master on the PROFIBUS DP system. The bus is designed according to the rules for PROFIBUS DP up to the segment coupler or link (see above). Within the PROFIBUS PA segment, practically all topologies are permissible (Figure 40.9).

The fieldbus comprises a two-core cable. According to IEC 61158-2, four different cable types (A, B, C, D) can be used, only two of which (cable types A and B) are shielded:

- Cable types A or B are recommended for new installations. Their cable shielding guarantees adequate protection from electromagnetic interference and thus the most reliable data transfer. With multi-pair cables (Type B), it is permissible to operate multiple fieldbuses on one cable, provided they have the same degree of protection. No other circuits are permissible in the same cable.

- Cable types C and D were defined for legacy installations. Practical experience has shown that they should be avoided where possible, since the lack of shielding means that electromagnetic interference characteristics generally do not meet the requirements described in the standard.

Table 40.8 lists the technical data of the four cable types as taken from the informative annex to the standard (i.e., this has not actually been specified). The electrical data determine important characteristics of the design of the fieldbus, such as distances bridged, the number of participants, and electromagnetic compatibility.

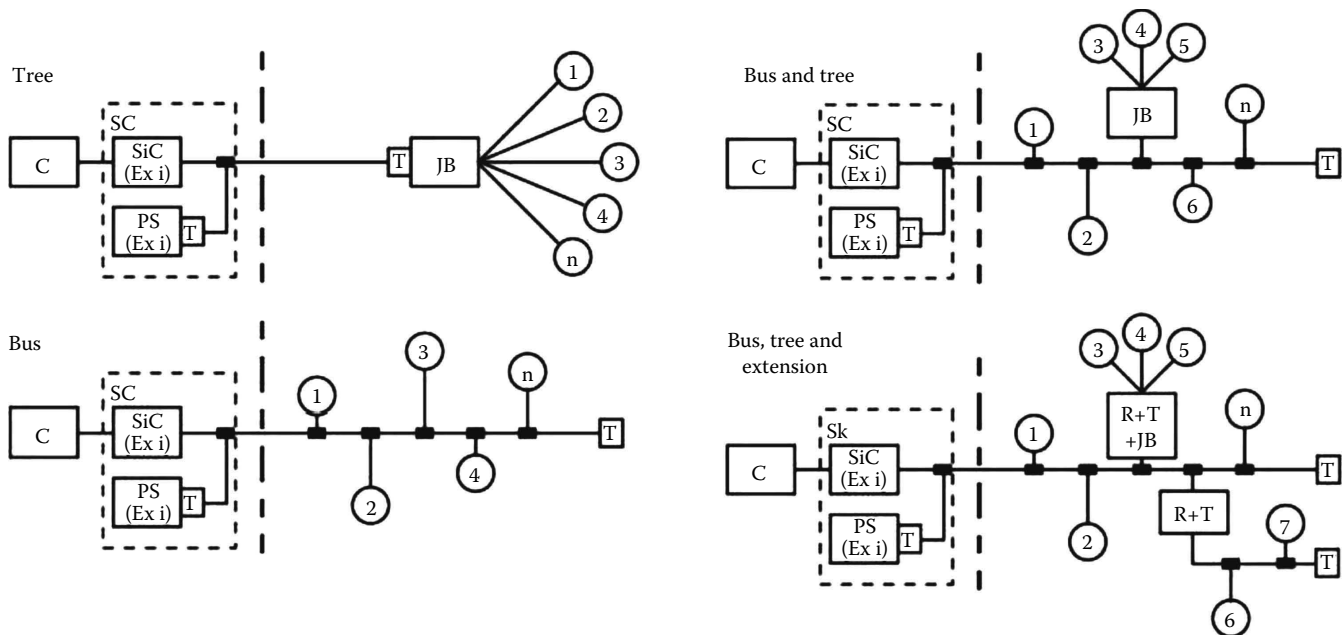
Cable for intrinsically safe applications as per the FISCO model must also satisfy the additional requirements listed in Table 40.9.

Cable types A and B as well as cable for intrinsically safe applications are sold by a number of cable manufacturers. A list can be obtained at the PROFIBUS site. The maximum bus length quoted in the tables is made up of the length of the main cable and the length of all spurs that are longer than 1 m. If repeaters are used, the maximum permissible cable length is

$$[\text{Length in table} \times (N + 1)]$$

where  $N$  is the number of repeaters, whereby maximum of four repeaters are permitted between station and master.

The line between distribution box and field device is described as a spur. In the case of safe applications, the

**FIG. 40.9**

PROFIBUS PA topologies: C, controller; SC, segment coupler; SiC, signal coupler, PS, power supply; T, terminator; JB, junction box, R, repeater, 1 ... n, field devices.

**TABLE 40.8***Cable Types According to IEC 61158-2, Annex C*

|                                               | <i>Cable Type A</i>          | <i>Cable Type B</i>                        | <i>Cable Type C</i>                   | <i>Cable Type D</i>                     |
|-----------------------------------------------|------------------------------|--------------------------------------------|---------------------------------------|-----------------------------------------|
| Cable construction                            | Twisted pair, shielded       | One or more twisted pairs, common shielded | One or more twisted pairs, unshielded | One or more untwisted pairs, unshielded |
| Core cross section                            | 0.8 mm <sup>2</sup> ; AWG 18 | 0.32 mm <sup>2</sup> ; AWG 22              | 0.13 mm <sup>2</sup> ; AWG 26         | 1.23 mm <sup>2</sup> ; AWG 16           |
| Loop resistance (DC)                          | 44 Ω/km                      | 112 Ω/km                                   | 254 Ω/km                              | 40 Ω/km                                 |
| Characteristic impedance at 31.25 kHz         | 100 W ±20%                   | 100 W ±30%                                 | —                                     | —                                       |
| Attenuation constant at 39 kHz                | 3 dB/km                      | 5 dB/km                                    | 8 dB/km                               | 8 dB/km                                 |
| Capacitive unsymmetry                         | 2 nF/km                      | 2 nF/km                                    | —                                     | —                                       |
| Envelope delay distortion (7.9–39 kHz)        | 1.7 μs/km                    | —                                          | —                                     | —                                       |
| Degree of coverage of shielding               | 90%                          | —                                          | —                                     | —                                       |
| Max. recommended bus length (including spurs) | 1900 m/6180 ft               | 1200 m/3900 ft                             | 400 m/1300 ft                         | 200 m/650 ft                            |

**TABLE 40.9***Safety Limits for the Bus Cable According to FISCO*

|                      | <i>EEx ia/ib IIC</i> | <i>EEx ib IIB</i> |
|----------------------|----------------------|-------------------|
| Loop resistance (DC) | 15–150 Ω/km          | 15–150 Ω/km       |
| Specific inductance  | 0.4–1 mH/km          | 0.4–1 mH/km       |
| Specific capacitance | 80–200 nF/km         | 80–200 nF/km      |
| Max. spur length     | ≤30 m                | ≤30 m             |
| Max. bus length      | ≤1000 m/3250 ft      | ≤1900 m/6180 ft   |

maximum length of a spur depends on the number of spurs longer than 1 m, Table 40.10.

In FISCO systems with type of protection EEx ia, the maximum spur length is 30 m.

As far as the specification is concerned, a maximum of the following is possible:

- Thirty-two stations per segment in safe areas
- Ten stations per segment in an explosive hazardous area (EEx ia IIC)

The number of stations that can actually be operated in practice is dependent on several factors, for example, current consumption and voltage at the last device. These factors must be determined during project planning.

The start and end of each fieldbus segment must be terminated with a bus terminator. The terminator may be a separate component or be integrated into a bus component:

- If the segment is in an explosion-hazardous area, the terminators must be certified to the FISCO standard.

- In the case of a branched bus segment, the device furthest from the segment coupler represents the end of the bus.
- If the fieldbus is extended with a repeater, every extension must also be terminated at both ends.

A number of manufacturers offer network components—terminators, junction boxes, T-pieces, multi-drop barriers (see the following text)—for both standard and hazardous area applications. Bus cables may be connected by screw terminals or standardized M12 plugs and sockets. The latter offer a quicker and more reliable method of connecting up a bus, but are, of course, more expensive.

### FISCO Model

The explosion protection concept for PROFIBUS PA is based on the type of protection “intrinsic safety Exi.” In contrast to other types of explosion protection, intrinsic safety is not confined to the individual unit, but extends over the entire electrical circuit. Not only must all circuits running into hazardous areas exhibit this type of protection, but all devices and terminators, as well as all associated electrical apparatus (e.g., PA links or segment couplers) must also be approved for the corresponding atmospheres.

In order to reduce the proof of intrinsic safety of a fieldbus system comprising different devices from different vendors to a justifiable level, the German PTB and various equipment manufacturers developed the FISCO model, now standardized as IEC 60079-27 [8]. The basic idea is that only one device supplies power to a particular segment, and the devices are limited in their capacitance and inductance

**TABLE 40.10**

*Maximum Length of a PROFIBUS PA Spur in Safe Areas as a Function of the Number of Spurs*

| Number of spurs      | 1–12         | 13–14       | 15–18       | 19–24      | 25–32    |
|----------------------|--------------|-------------|-------------|------------|----------|
| Max. length per spur | 120 m/390 ft | 90 m/290 ft | 60 m/185 ft | 30 m/92 ft | 1 m/3 ft |



example, a device configuration tool. The field devices on the PROFIBUS PA segment are the slaves. The actual mode of access differs slightly depending on whether a segment coupler or link is used to connect the PROFIBUS PA segment to the PROFIBUS DP system.

As mentioned earlier, segment couplers are transparent as far as the PROFIBUS DP master is concerned, so that they are not mapped in the PLC. They simply convert the signals and power the PROFIBUS PA segment. They do not need to be configured nor are they assigned an address. In contrast, the field devices in the PROFIBUS PA segment connected to the segment coupler are each assigned a PROFIBUS DP address and behave as PROFIBUS DP slaves, that is, they can be assigned to only one Class 1 master but be accessed by several Class 2 masters. Communication via a segment coupler is shown in Figure 40.11:

1. The Class 1 master transmits and receives field device process data using the MS0 (cyclic) and MS1 (acyclic) protocols.
2. The Class 2 master transmits and receives field device configuration data using the MS2 (acyclic) protocol.

In addition to the standard single-channel segment coupler, so-called gateway-type segment couplers exist. These allow several segments to be connected to one central coupler unit. As far as media access is concerned, they operate in exactly the same manner as the normal segment coupler, that is, each PROFIBUS PA device connected to the coupler must have a unique PROFIBUS DP address independent of the segment to which it is connected. The major difference to a standard segment coupler is that a range of transmission rates is supported on the PROFIBUS DP side. This allows better cycle times to be attained in mixed PROFIBUS DP/PA systems.

In contrast to a segment coupler, a link is recognized by the PROFIBUS DP master and is a participant in the PROFIBUS DP system. It is assigned a PROFIBUS DP

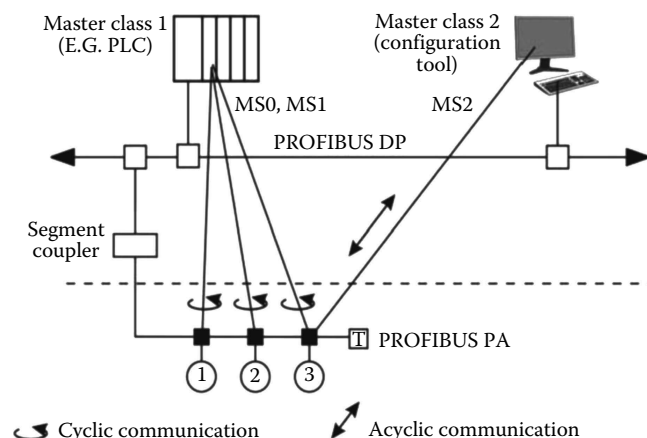


**FIG. 40.11**  
*PROFIBUS PA media access via segment coupler.*

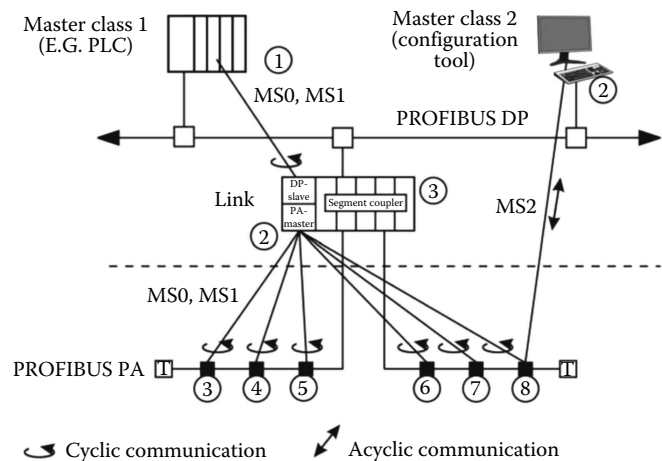


**FIG. 40.12**  
*PROFIBUS PA media access via link.*

address and thus becomes opaque and visible to the PLC. The field devices on the PROFIBUS PA side can no longer be directly polled using the MS0 and MS1 protocols. Instead, the link collects the device data in a buffer, which can be read cyclically by a Class 1 master (see Figure 40.12).

On the PROFIBUS PA side, the link acts as the PA master. It polls the field device data cyclically and stores them in a buffer. Every field device is assigned a PROFIBUS PA address that is unique for the link, but which may be used in a segment connected to another link. When the link is accessed by a Class 2 master with the acyclic services, it is quasi-transparent. The desired field device can be accessed by specifying the link address (PROFIBUS DP address) and the device address (PROFIBUS PA address).

Like gateway-type segment couplers, links support a range of transmission rates on the PROFIBUS DP side. Since they are not transparent, they must be engineered in the network configuration tool by means of a GSD file. Among other things, all the cyclic I/O data of the connected slaves must be entered into this file. Special software applications are supplied to aid configuration. In contrast to segment couplers, a link is limited in the amount of PROFIBUS PA data it can transmit. The total amount of cyclic I/O data permitted, that is, the accumulated total from all PROFIBUS PA devices connected to the link, is 244 bytes for input and 244 bytes for output data.

## Network Configuration

Network configuration for PROFIBUS PA is identical to that of a PROFIBUS DP system. The user requires a GSD file for each of the devices that tells the network configuration tool what I/O data are offered, what profile version is supported, etc. An EDD file is required for device configuration and a bit map for representation of the device in the network tree. The only difference to PROFIBUS DP is that the transmission rate on PROFIBUS PA is fixed at 31.25 kbit/s.

The user first builds up the network offline in the network configuration tool, assigning virtual addresses to the controller and each of the slaves as described earlier. The controller is then configured by selecting the correct bus parameters for the segment coupler/link and the PROFIBUS DP transmission rate in use. Normally, standard parameter sets are offered by the network configuration tool, but these may need to be modified, in particular when the device configuration tool accesses the network through a gateway acting as Class 2 master. Then each of the slaves is configured in turn by selecting the parameters it is to send and/or receive over the bus, [Figure 40.7](#).

As far as the physical network is concerned, it only has to be ensured that a field device really has the address it was assigned in the configuration tool. Normally the configuration tool will scan the network for “live” devices, that is, those that are operational and have a unique PROFIBUS DP address. Where devices have DIP switches for address setting, the network can be pre-configured prior to start-up. Devices with software addresses can be configured individually before commissioning or must be introduced one by one to the network, and then assigned an address by the configuration tool.

The most frequent network configuration fault is a mismatch of the bus parameters set in the various devices on the PROFIBUS DP side, where all devices must be set to operate at the same transmission rate. Component manufacturers give recommended settings here. If a device does not appear in the system tree, the most frequent cause is an address conflict. If the network has been designed according to good practice guidelines [9] and PNO certified devices have been used throughout, no further problems should be encountered.

## Device Configuration

Device configuration on a PROFIBUS DP/PA network is handled by the MS2 protocol using acyclic polling services. The configuration tool may be connected directly to the PROFIBUS DP network, see [Figure 40.8](#) or access it via an Ethernet/PROFIBUS DP gateway, see [Figure 40.3](#). Since the PROFIBUS PA standard offers the possibility of interconnecting devices from different vendors, a profile set has been defined that contains standardized device parameters and functions:

- Mandatory parameters must always be present.
- Optional parameters are only present when required, for example, for a particular transmitter type such as a Coriolis mass flowmeter.
- Manufacturer-specific parameters are used to realize device functions that are not in the standard profile.

If a device contains manufacturer-specific parameters, a manufacturer's configuration tool or a device description file is required for its operation. Devices conforming to the device profile can always be operated to a limited extent by

means of a profile device description that contains the mandatory and optional parameters. If the device configuration tool is an FDT-frame, then a device DTM (device type manager) or a Profile DTM can also be used for configuration.

PROFIBUS PA devices manage their parameters in block objects. Within the blocks, the individual parameters are managed using relative indices. [Figure 40.13](#) shows the block model. Every device has four blocks: device management, physical block, transducer block, and function block. For a measuring device, the sensor signal is converted to a measured value by the transducer block and transmitted to the function block. Here the measured value can be scaled or limits can be set before it is made available as the output value to the cyclic services of the PLC. For an actuator, the processing is in the reverse order. The PLC outputs a set point value that serves as the input value to the actuator function block. After any scaling, the set point value is transmitted to the transducer block as the output value of the function block. It processes the value and outputs a signal that drives, for example, the valve to the desired position.

The parameters assigned to the individual blocks use the data structures and data formats that are specified in the PROFIBUS standard. The structures are designed such that the data are stored and transmitted in an ordered and interpretable manner. All parameters in the PROFIBUS PA profile, whether mandatory or optional, are assigned an address (slot/index). The address structure must be maintained, even if optional parameters are not implemented in a device: this ensures that the relative indices in the profile are also to be found in the devices. With the exception of

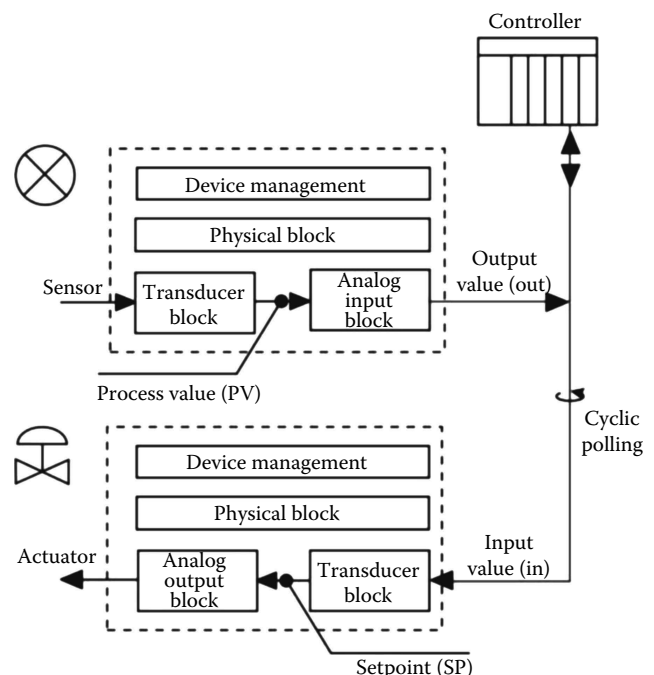


**FIG. 40.13**  
Block model of PROFIBUS PA sensors and actuators.

the device management, standard parameters are to be found at the beginning of every block. They are used to identify and manage the block. The user can access these parameters using the acyclic services, for example, by means of a configuration tool.

The *device management* comprises the directory for the block and object structure of the device. It gives information about which blocks are present in the device, where the start addresses are located (slot/index), and how many objects each block holds. By using this information, the application program of the master can find and transmit the mandatory and optional parameters of a profile block.

The *physical block* contains the properties of the field device. These are device parameters and functions that are not dependent upon the measurement method, for example, identification, installation, and operational data, as well as application-independent diagnostic messages.

*Transducer blocks* stand as separating elements between the sensor or actuator and the function block. They process the signal from the sensor (or actuator) and output a value that is transmitted via a device-independent interface to the function block. The transducer blocks reflect the measurement or actuating principles. They also contain generic parameters that allow every device to be configured by a basic operation mode, even when the corresponding GSD file is not available to the configuration tool. Profile 3.0 currently contains specifications for “analog” transmitters; discrete I/O for switches; and electromagnetic and pneumatic transducer blocks for actuators.

*Function blocks* contain the basic automation functions. Since the application program demands that a cyclic value always behaves in the same manner, the blocks are designed to be as independent as possible from the actuator/sensor and the fieldbus. There are currently five standardized function blocks:

- *Analog input blocks*: fed by a sensor transducer block, allowing simulation, characterizing, and scaling of the output value.
- *Totalizer block*: used when a process variable must be summed over a period of time, for example, for flowmeters, and fed by a sensor transducer block.
- *Discrete input block*: fed by a limit switch transducer block, allowing signal inversion.
- *Discrete output block*: feeding the transducer block of a binary actuator.
- *Analog output block*: feeding the transducer block of an “analog” actuator.

Details of the structure and parameters of the blocks can be found in the PROFIBUS standard and manufacturers’ literature.

PROFIBUS PA Profile 3.0, which laid the foundations for device classification, was introduced in 1999. Since then, two extensions have been published. Profile 3.01, published in 2004, introduced a uniform device identification scheme

and implemented simplified device diagnosis based on the NAMUR recommendation NE107 [10]. This sorts error messages into four classes: “maintenance required,” “failure,” “functional check,” and “out of specification,” allowing the user to assess the severity of the alarm before deciding whether the detailed information held by the device is needed. Shortly afterward, PROFIsafe for PROFIBUS PA was published as a separate paper.

The current version Profile 3.02, published in 2008, addresses the simplification of device integration over its entire life cycle and also speeds up parameter upload/download [11]. One of its primary aims is to make device exchange as easy as it was for 4–20mA technology. To this end, mechanisms have been standardized, which allow a device to assume the functionality of a predecessor version. There are two aspects involved: on one hand, the automatic identification of the expected predecessor version, and on the other, the automatic switchover to this version by the successor device. After exchange, the host application recognizes the new device and tells it, on the basis of the EDD and GSD/DTM files that are stored as part of the project, what version it expects the new device to be. The new device either confirms that it is the expected version or it recognizes the mismatch and changes its own version to the one expected. The new device can thus be integrated without the immediate necessity to reconfigure the project. The correct GSD and DTM/EDD can then be integrated during routine system maintenance at a later date.

## Network Design

As mentioned previously, there are differences between what is theoretically possible for a PROFIBUS DP/PA network and what must actually be done in practice. On the PROFIBUS DP side, depending upon controller and network infrastructure, the number of slaves per PROFIBUS DP interface may be less than the maximum of 126 allowed by the standard. More information is to be found in the manufacturer’s instructions. When a PROFIBUS PA segment is designed, two general factors must be considered:

- The physical limitations of the segment dictated by the available power and voltage, the cable used, and the type of protection that must be upheld
- The data transfer limitations dictated by the permissible telegram length and cycle times

## Telegram Length

Standard telegrams of a maximum length of 244 bytes are used to exchange data over the PROFIBUS PA segment. An “analog” measured value and status requires 5 bytes, and discrete value and status 2 bytes. A device may output more than one measured value, for instance, a coriolis flowmeter may offer up to 10 different outputs.

When the segment is operated through a segment coupler (i.e., each device is polled individually), the data exchange presents no restriction to segment size. Even when all nine input values of our Coriolis flowmeter in [Figure 40.8](#) are activated, only 45 bytes are required to transmit all values. If, however, the segment is operated through a link, the PROFIBUS DP telegram length comes into play because the link collects the segment data before forwarding it to the controller in one telegram. The permissible telegram length is limited

1. By the buffer size of the link, for example, 244 bytes
2. By the maximum telegram length of the PLC

Most masters today use a telegram length of 244 bytes when used with a link or segment coupler. There still are, however, systems on the market that are restricted to 122 bytes. Again the manufacturer's instructions should be consulted before designing the segment. The telegram length imposes an upper limit on the number of bytes that can be generated within the PROFIBUS PA segment connected to a link and, hence, on the number of devices it can support. If the master supports only 122 bytes, then only 24 "analog" devices offering 5 bytes each can be accommodated on the segment. This number is reduced when, like flowmeter, the devices have been configured to deliver more than one measured value.

### Cycle Times

In addition to the amount of data, the cycle times must also be considered when the PROFIBUS PA segment is planned. Data exchange between a PLC (a Class 1 master) and the field devices occurs automatically in a fixed, repetitive order. The cycle times determine how much time is required until the data of all the devices in the network are updated. The more complex a device is, the greater the amount of data to be exchanged and the longer the response time for the exchange between PLC and device. The total cycle time for the updating of network data can be estimated as follows:

Total cycle time = Sum of the cycle times of the field devices  
 + internal PLC cycle time  
 + PROFIBUS DP system reaction time

The cycle time of the PLC is typically 100 ms, that of the field devices typically 10 ms for one measured value and 1.5 ms for each additional measured value. The PROFIBUS DP system reaction time is normally given by the token rotation time. In a mono-master system, however, it is dependent upon the number of slaves and the retry setting. Both are dependent upon the transmission rate, which may range from 45 kbit/s to 12 Mbit/s depending upon the components used. The total cycle time of a large system can be reduced considerably by the use of links, since controller does not have to poll all the

slaves in the network individually. Since the internal cycle of the link runs independently of the controller, the total refresh time is then primarily dependent on the slowest link.

### PROFINET

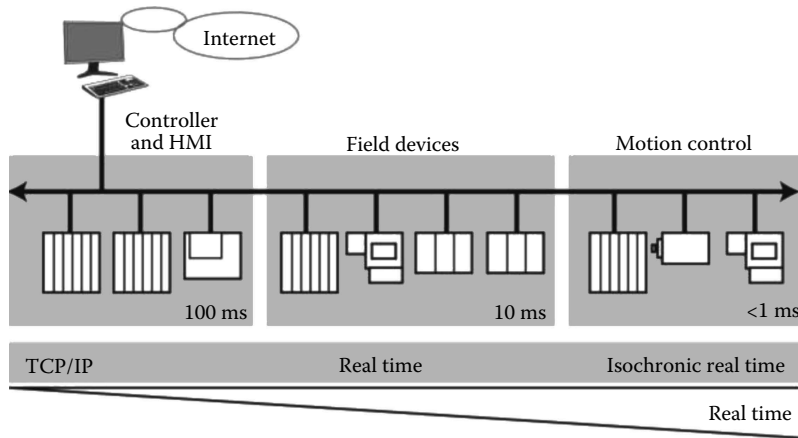
PROFINET is the Ethernet-based automation standard of PROFIBUS International. It has two facets: PROFINET CbA (component-based automation) and PROFINET I/O (integration of decentralized periphery in PROFINET), both are discussed in the following text. PROFINET technology was standardized as Type 10 in IEC 61158 [2] and in IEC 61784 [4] in 2003 and is intended for use in a wide range of industrial applications, for example

- Production systems
- Assembly systems
- Systems in the automotive industries
- Systems in the food and beverage industries
- Packaging systems

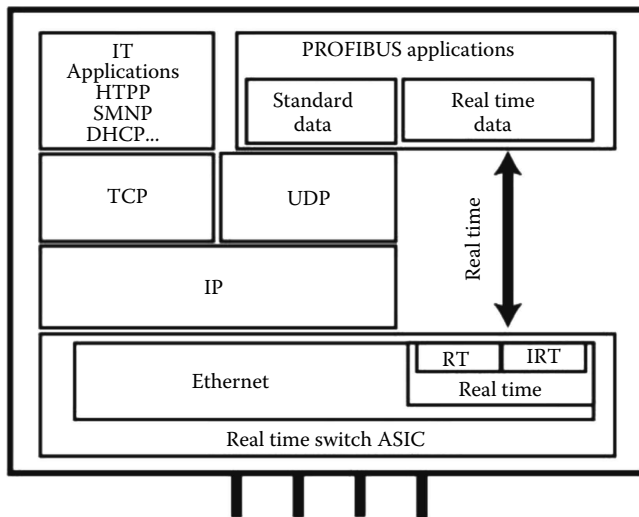
PROFINET allows the implementation of distributed automation structures, integration of simple decentralized field devices, for example, connected to a PROFIBUS PA segment, as well as the operation of motion control applications. As can be seen in [Figure 40.14](#), each of these applications places different demands on the system with respect to the response times and RT operation.

PROFINET recognizes this fact and provides a modular solution, which treats each application as a separate "control island." Such islands might be, for example, a SCADA system for monitoring and operating the plant, a control network for flow, ratio, and level control of a reactor, a complete filling machine, or an industrial robot. It specifies those functions required for an integrated automation solution, ranging from network installation to web-based diagnosis. The resulting modular structure permits simple scalability. PROFINET operates over a high-speed (100 Mbit/s) switched Ethernet TCP/IP backbone. This ensures full duplex communication, isochronous communication, and prioritization of RT frames where required. A specially developed PROFINET chip enables switch integration into a device and controller.

The communication stack is shown in [Figure 40.15](#). It can be seen that PROFINET uses Ethernet at three performance levels for communication between I/O devices. Engineering and time-uncritical data are transferred via transmission control protocol/internet protocol (TCP/IP) and user datagram protocol (UDP). For time-critical process data, for example, alarms, a real-time (RT) channel is available. It is implemented as software based on available controllers. For motion control, isochronous real-time (IRT) communication is available. The network management covers all the functions for the administration of PROFINET devices in Ethernet networks. These include device and network configuration, for example, issue of IP parameters based on standards like DHCP (dynamic host

**FIG. 40.14**

Three aspects of PROFINET operation.

**FIG. 40.15**

PROFINET communication stacks.

configuration protocol) as well as network diagnosis based on standards like SNMP (simple network management protocol); integration of web functions, for example, access to components by means of standard technologies from the Internet field such as HTTP (hypertext transfer protocol), XML (extended mark-up language), HTML (hypertext mark-up language), and addressing with scripting; and field device integration.

### Component-Based Automation

Component-based automation is best explained by taking the example that PROFIBUS & PROFINET International uses in its own presentation—bottling in brewing or soft drinks production. The bottling is done by a number of machines that wash, fill, seal, and pack the bottles. Prior to this the product must be manufactured by a classical process control application. [Figure 40.16](#) illustrates the task in question. First, the

individual machines or production units must communicate with each other. Second, there must also be communication between the devices within the machine or production unit.

The network architecture depends on the nature of the processes involved and the demands they make on control. Typically, however, the sealing and packing of bottles are purely factory automation tasks requiring IRT communication. Washing and filling are hybrid tasks and the production of the beer or soft drink is a process-automation task. [Figure 40.17](#) illustrates the architecture to be expected, the production process being a PROFIBUS DP/PA task and the washing and filling a typical PROFIBUS DP task today.

PROFINET considers the machines and systems to be divided into technological modules, each of which comprises mechanical, electrical, and software components. The functionality of the technological modules is encapsulated in the form of PROFINET components. These have standard interfaces for use in a PROFINET engineering tool. They can be used as building blocks, combined as required and are easily reused. The PROFINET components for all technological modules in a machine or component assembly are supplied by the manufacturer, for example, on a CD-ROM.

The technological modules are basically global function blocks for the machine or component assemblies in the plant and can be used within a PROFINET engineering tool to build up a logical view of the plant ([Figure 40.18](#)). The standard interfaces allow the logical sequences to be programmed in a graphical environment. Thus, for instance, a connection between the “Finished” output of one machine to the “Start” input of another will cause the appropriate message to be sent over Ethernet and the downstream machine will start up when the upstream machine has finished its task.

The engineering tool is also used to build up a view of the PROFINET and PROFIBUS DP network, the technical modules forming the link between the two views. Fieldbus systems are connected to the PROFINET backbone by proxies ([Figure 40.19](#)). In our example, the fieldbus is PROFIBUS

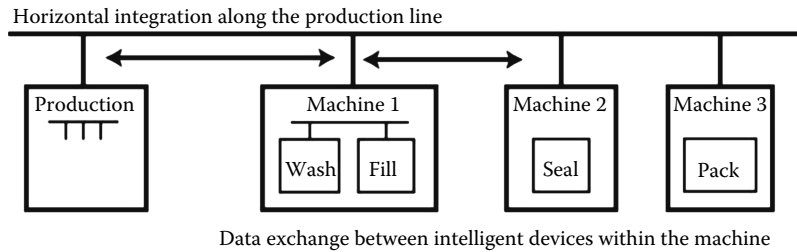


**FIG. 40.16**  
Schematic diagram of automation tasks in a brewery or soft drinks plant.

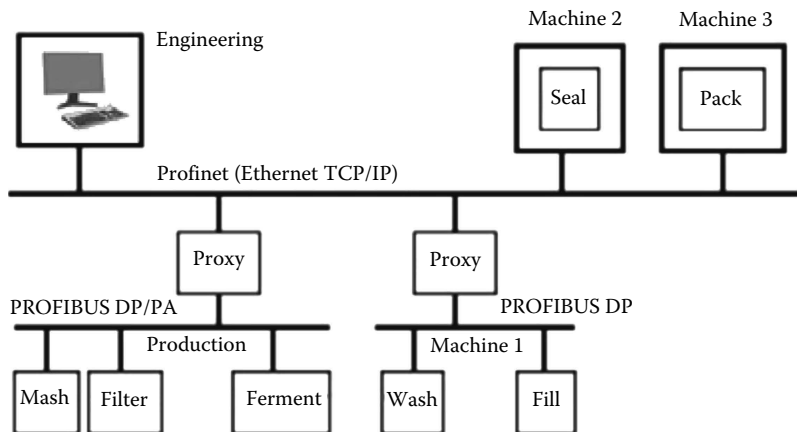


**FIG. 40.17**  
Possible plant architecture for brewery or soft drinks plant.

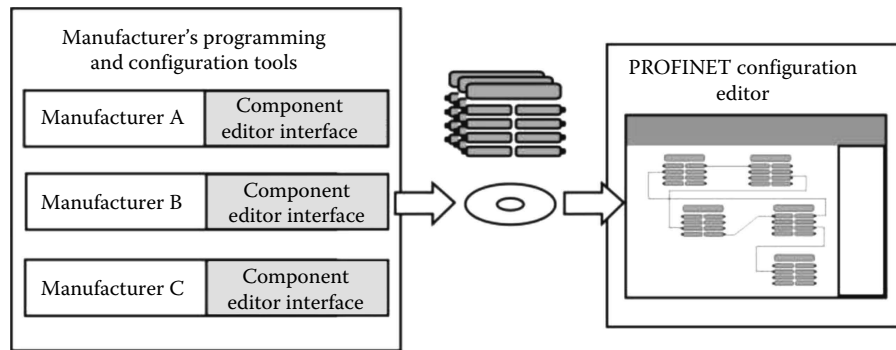


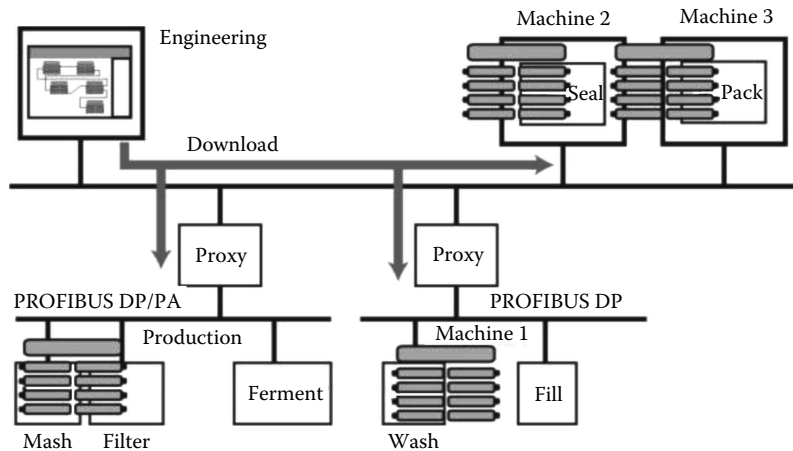
**FIG. 40.18**  
Standardized global function blocks simplify the PROFINET configuration.

DP/PA, but it is also possible to integrate MODBUS, AS-i, INTERBUS, etc. When the tool goes online, that is, the various components are connected physically to the network, the logical project is downloaded to the connected machines and devices. The system can then be started up with pre-configured links.

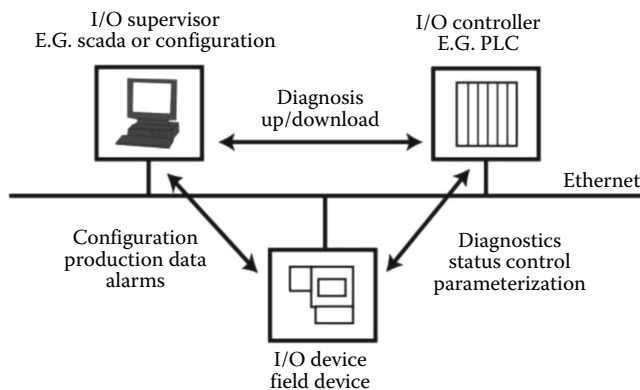
### I/O Integration

As can be seen from the above example, PROFINET allows direct interfacing of decentralized field devices on

Ethernet, supporting flat communication hierarchies in automation. All the devices used are connected in a consistent network structure and therefore provide open communication throughout the entire production system. PROFINET defines three types of I/O device: an *I/O controller* is a device containing the control program and managing data exchange to assigned field devices, an *I/O device* is a field device connected to the I/O controller and an *I/O supervisor* is the HMI and diagnostic station. Figure 40.20 shows the types of data that are exchanged between the three types of devices.

**FIG. 40.19**

The links are downloaded to the machines and the system is ready for start-up.

**FIG. 40.20**

Data exchange between PROFINET I/O devices.

The integration of existing field bus applications is accomplished with the proxy concept. The signals from the PROFIBUS DP/PA field devices (decentralized peripherals), for example, are processed directly in the assigned controller. The controller communicates with other PROFINET I/O devices via a proxy. PROFIBUS DP/PA devices are integrated in the controller by means of standard GSD files. The direct integration of the decentralized field devices in the PROFINET system itself is an optional add-on to distributed automation. Here a special GSD file, GSDML (general station data mark-up language) written in XML, is used.

The PROFINET physical layer specifies either the use of four-core, Category 5, copper cables or twin fiber-optic cables. Transmission rate is 10/100 Mbits/s, whereby performance is optimized for 100 Base-Tx. Copper cables are classified as Type A, Type B, Type C, and outdoor, depending on application and shielding. Type A and Type B are for permanent or flexible installation, Type C is for rugged industrial environments, and outdoor cable is water and weatherproof. A further type, a hybrid eight-core cable that also carries a

24 V power supply, is also available. Standard or industrial RJ45 or M12 connectors are used for copper cables. The network structure is basically linear, whereby there is a specific degree of networking for each machine/system. PROFINET provides the device manufacturer with clear specifications for device interfaces and their wiring. The PROFINET Installation Guide [12] provides the system manufacturer/operator with simple rules for the installation of Ethernet networks. More information can be found at [www.profibusb.com](http://www.profibusb.com).

## CONCLUSION

Since PROFIBUS first came on the market in the early 1990s, it has firmly established itself as one of the leading fieldbuses for process control, despite the fact that its installed base lies mainly in factory automation. This in fact has turned out to be one of its strengths, since its main rival, FOUNDATION fieldbus, has less to offer in the way of the drives, motor control centers, or frequency converters, which are also essential to process control. It is not surprising, then, to find an increasing number of PROFIBUS DP integrations into FOUNDATION fieldbus high-speed Ethernet (HSE) to provide the missing components. Traffic is not one way, and PROFINET can also integrate FOUNDATION fieldbus systems via proxies: a case of the two protagonists of the fieldbus wars finding their way to peaceful coexistence?

With a full palette of measuring devices and actuators, PROFIBUS DP/PA has penetrated into most processing industries, particular strongholds being food and beverages and water/wastewater applications. Its introduction into chemical and pharmaceutical plants was slowed down by the conservative stance of the industry to its use in hazardous applications; however, after the influential NAMUR chemical manufacturer's organization approved its use, it has also penetrated this field. Where PROFIBUS seems to have little chance is in the petrochemical industry, which has adopted FOUNDATION fieldbus as the preferred standard.

PROFIBUS has continued to be innovative, constantly seeking new ways to satisfy user demand. They were one of the first organizations to add functional safety to their protocol and were the driving force behind the FDT initiative, while still recognizing the advantages of standardized EDDs. With the introduction of PROFINET, users now have an Ethernet control backbone, which can handle a variety of applications. When first introduced, there was talk of PROFINET replacing PROFIBUS DP as control bus for PROFIBUS PA applications, but as yet, no equipment has come on the market. There is no PROFIBUS wireless protocol, although this is “integrated” in the ISA 100.11a wireless standard, so perhaps this is where the next innovation will be found. No matter what the next step is, PROFIBUS has proved to be reliable and sustainable.

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